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Commentary

The Essential Elements and Value of Scientific Research: Consistent Methods, Communication, and Broad Dissemination to a Global Community

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As a postdoctoral researcher, I sit in the great maelstrom between the carefree optimism of graduate-student life and the relative security of a tenure-track professorship. My research is just as interesting to me as it always was, but contracts are temporary and the competition for long-term employment is fierce. The uncertainty of my professional future has made me revisit my ideas on what I like about science and how I see a scientist contributing to society. Of course, science can mean different things to different people. Some see it as a body of knowledge accrued by scientists. Others see it as a process by which scientists come to understand the natural world. It can be practical and applied, but also esoteric and theoretical. In reflection, I have come to understand that by following an agreed-upon set of rules, scientists can instill confidence in the conclusions they are able to draw. Science is process oriented, and in providing society with a framework for posing questions, collecting information, conducting analyses, and drawing informed conclusions based on the best available information, the scientific method is one of humanity's greatest cultural contributions.

I would guess that my first exposure to science was quite typical. As a child, I was an avid reader and I especially enjoyed books about dinosaurs. I was awed by creatures that were so much more spectacular than anything I had ever dreamed could be real. As I got older, I became more interested in books about the solar system and was

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fascinated to learn about distant planets, their harsh environments, and the possibility there might even be life elsewhere in the universe. My family encouraged my interest in science by taking me on visits to the science centre, on outings to museums, and for hikes through a local wetland (this was probably my first exposure to ecology!). They also bought toys to foster my interest in science, but I remember these being of much less interest to me. Despite my clear passion for science and technology, I simply was not a tinkerer, and showed little interest in building models or conducting actual experiments. What excited me was talking about what I had learned from my books. I would talk the ear off anyone who would listen, and was luckily more often indulged than sent packing. I thought it was amazing that people were able to discover things about animals that existed so long ago and were able to study objects that were so far away. I wanted to know more about how they were able to do this work. Even though I was initially impressed by its ultimate findings, I have since learned that it is the process of science that is, and probably always was, most interesting to me.

Leaving room for some methodological deviation, most scientific endeavour entails following a common sequence of activities: observation, hypothesis formation, experimentation, verification, and disclosure of results. By following this general framework, a scientist prioritizes this process of discovery over finding any one particular result. In this way, no matter what claim a scientist makes, the goal is for anyone to be able to verify any conclusion as long as that person follows a similar set of rules. These rules represent a common language, and they allow people from all over the world to contribute to a body of knowledge that expands with every generation of new scientists. I find this collaborative spirit truly inspirational, and my training in this scientific method is what has allowed me to progress from simply talking about the science I read about to actually contributing as a professional scientist to the legacy I inherited from my like-minded forebears. Of course, this worldwide investment in knowledge development only works well when scientists are free to investigate and communicate their results, and this freedom must be vigilantly defended if the scientific method is to have a global impact on the development of science policy.

After realizing that I am more enamoured by the process of science than by its specific outcomes, it occurred to me that the field in which I ended up is almost entirely the result of a series of coincidences and subsequent positive experiences in different research labs. As an undergraduate, I gravitated toward the life sciences and eventually took a strong interest in ecology. I was fascinated by the complexity of community ecology in particular. The number of questions that could be posed was dwarfed only by the number of possible interactions among species, and I quickly responded to the complexity of approaches employed in this branch of science. I joined a lab that used freshwater microcosms as a model ecosystem and learned how to do experiments. In graduate school, I transitioned to studying diversity of lake plankton communities and learned new analytical and data collection techniques, in addition to an appreciation for finding applications of ecological theory in natural ecosystems. Currently, I use data collected over decades to work at the scale of whole ecosystems, and my primary research goal is to identify how environmental change affects water quality in lakes.

In a political culture where science funding is increasingly allocated according to the perceived relative merits of applied over basic research, freshwater science is one field

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where practical research applications are easy to find. Less than 1% of the Earth's water is drinkable. If we are to operate under the assumption that people will be no less thirsty in 30 years than they are now, it should be clear that we need to be fully aware of the threats posed to water quality by a great diversity of environmental stressors. These stressors include climate change, cultural eutrophication owing to population growth, the resultant intensification of agricultural activities, pollution from massive global industrialization, disruption to local food webs, and many others. Understanding the relative importance of these complex and interacting stressors poses both a daunting problem and a tantalizing intellectual puzzle. The stakes are also very high, with access to fresh water having been recognized by the United Nations as a fundamental human right.

For these reasons, I believe that freshwater scientists should strive to offer practical insights, particularly when the work is funded by public money. Taxpayers should expect a return on their investment in this work, and scientists, policymakers, and local watershed managers need to work together to protect future water security. Freshwater research is currently being done using diverse approaches, including manipulative experiments, long-term monitoring programs, and the development of statistical models that can predict future outcomes based on changes that have occurred in the past. Understanding how we might expect water quality to change in the future as a result of environmental and anthropogenic pressures gives a powerful impetus to conserve our aquatic resources in the present and is an important contribution of science. Still, I strongly believe that the paramount contribution of science to society is in the broader dissemination of its methods, thereby providing a basis for effective science policy creation.

Perhaps the best thing about science is that, strictly speaking, scientists do not ask anyone to simply take their word for anything. As long as methods and procedures are clearly communicated, any result can be verified, and any conclusion can be scrutinized for its veracity. Empirical results are weightier than opinions, and more often than not a sizeable body of evidence must accumulate before a hypothesis can be deemed convincing. Most importantly, a scientist always reserves the right to develop new opinions based on the best available data, particularly when foundational evidence is contradicted by new information. There is no better way to approach the development of public policy than by depending on objective interpretation of information, collected according to a transparent and well-communicated method of hypothesis-based inquiry.

Described in this way, science can easily be thought of as a coldly rational, impersonal pursuit. One of the things I like best about science, however, is the impressive opportunity for creativity that it can present. Of particular interest to me are the diverse ways that different scientists will approach the same questions, depending on each person's unique combination of personal and professional experiences. Inspiration will set off a chain reaction of ideas, potential approaches, and resultant solutions. Even though the general framework of posing questions, collecting information, conducting analyses, and drawing informed conclusions based on those results is a common touchstone, each scientist will interpret the specific procedural strictures differently, and will in this way offer unique insights.

The resultant wealth of information provides the opportunity for all scientists and policymakers to interpret and organize the results of scientific research and, hopefully, use it to make informed decisions regarding the management of Canada's natural resources. In providing a consistent, organized, and repeatable framework for understanding the natural world, science has established a means by which people can collaborate most effectively in the development of science policy. This is the most important contribution science makes to society.

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